GROUND PLAN OF A DYNAMIC METEOROLOGY

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[Woods Hole Oceanographic Institution, Woods Hole, Mass., July 10, 1931]

This is a summary of a discussion recently presented at a meeting of the New England branch of the American Meteorological Society held at the Massachusetts Institute of Technology in Cambridge.

The discussion was based on T. Bergeron's recent paper "Richtlinien einer dynamischen Klimatologie," appearing in Meteorologische Zeitschrift for July, 1930. This discussion is not limited strictly to the contents of Bergeron's paper, therefore statements made here are to be attributed directly to Bergeron only when that is specifically stated.

Bergeron's excellent effort toward a rationalization of the fundamental facts of climatology is particularly significant in two respects: (1) He has suggested a new and promising method of approach to the whole problem of the representation and explanation of climate, and (2) he offers for the first time practical suggestions as to how to introduce into statistical climatology some of the concepts, in modified form, which in recent years have been developed in connection with the analysis of synoptic weather maps.

Bergeron's main thesis may be stated somewhat as follows: Hitherto climatology has been essentially the systematic compiling of statistics on the individual meteorological elements, without much organized attempt to get at the underlying dynamic or thermodynamic phenomena in their entirety. We have complete charts of the distribution of atmospheric pressure, rainfall, temperature, wind, cloudiness, etc., but usually very little idea of just how the distributions of these elements tie up with one another, or just what sort of atmospheric activity, in toto, is behind these observed distributions. Bergeron points out, however, that this is by no means always the case. For example, in the more regular circulations of the subtropics, such as the trade wind systems, it is possible even from our present types of climatological charts to draw conclusions as to the thermodynamic basis of the observed atmospheric activity. Especially clearly marked are the more effective orographical influences in such regions. The more regular monsoon systems furnish another instance of a type of circulation which so definitely controls the climate of certain regions that it may be described completely in terms of a single atmospheric phenomenon. The best illustration of this is the Indian monsoon, where the underlying thermodynamic process is so well understood that it is necessary only to characterize a given period as one of weak or strong monsoonal activity in order to convey a comprehensive picture of the climate or climatic changes during the time in question. Here again orographical effects are readily recognized. But in general over the greater part of the temperate and northerly latitudes climatology offers no unifying picture of the prime thermodynamic forces controlling the climate. This is what a dynamic climatology should do. Therefore Bergeron undertakes to show how the concepts of air masses and fronts may be modified to furnish a key to the development of a comprehensive dynamic climatology.

If we look at almost any synoptic chart which covers a considerable area on the earth's surface, one of the things that stands out most strikingly is the existence of large scale air currents or large bodies of air at rest in which the meteorological elements are distinctly uniform in their horizontal distribution. Such extensive bodies of air which approximate a state of horizontal homogeneity in their properties we refer to as air masses. Their occurrence is due essentially to two facts. These are (1) the existence of extensive sources, or regions on the earth's surface where conditions are so uniform that the overlying atmosphere acquires horizontal homogeneity in its properties. Examples of such sources are the Arctic ice fields, snow-covered northerly continents in winter, the warm subtropical oceans, and continents, especially southerly or semiarid regions in summer; (2) the occurrence in the general circulation between subtropical and subpolar regions of large scale atmospheric movements. This makes possible large displacements of air masses from their sources with a considerable degree of conservation of certain of their characteristic properties, rather than the rapid turbulent mixing and loss of air mass characteristics which would occur if the latitudinal transport of air took place in small, disordered currents instead of in the large branches observed in such circulations.

Evidently if the existence of air masses of more or less definite characteristic properties be accepted, then their classification according to their characteristic properties and their detection on the synoptic chart become a material aid to weather forecasting. Bergeron has indicated further a classification of air masses which may be made a material aid to the understanding of climate. According to him there are two distinct methods of procedure in classifying air masses, each with its particular advantages.

(1) *The integral method.*—This method consists in picking out the most conservative or nonvariable properties of an air mass, such as the potential temperature or specific humidity, and using the characteristic seasonal values of these quantities for the classification and identification of the air masses appearing on the synoptic chart for a given region. Since the characteristic values of these conservative properties of air masses depend upon both the properties of the mass at its source and the sum total (integral) of the modifying influences to which the mass has been subjected in following its path from the source, it is evident that this method of classi-

fication can be used to advantage only at stations where a series of carefully analyzed synoptic charts based on observational material from a considerable area are prepared, for the complete life history of the air mass must be known. This follows from the fact that it is possible for two quite different air masses which have followed widely separated trajectories to arrive at the same point with approximate similarity of their conservative properties at the ground, yet with very significant differences in their vertical structure. At a forecast center where observational material from a wide network of stations is at hand, this system of air-mass classification is most advantageous, because the characteristic air masses for any given locality depend definitely upon the usual air mass sources and trajectories in that region. When the forecaster becomes familiar with these, he knows in detail the characteristics and therefore the type of weather to be expected locally with each particular air mass. On the other hand, because air masses classified in this way are essentially particular rather than general in nature, i. e., are dependent on local or regional geography, they are useless to the climatologist, who must have a perfectly general classification applicable anywhere on the earth's surface.

(2) *The differential method.*—This method consists in picking out the most variable or non-conservative properties of the air mass, in particular the lapse rate at lower levels and making the changes (differences) in the air mass properties effected by its most recent history, as indicated by the lapse rate, the basis for the air mass classification. On this principle all air masses may be grouped in the following four perfectly general classes:

(a) Warm: Air masses warmer than the surfaces over which they are moving, hence with a tendency toward increasing stability and stratification.

(b) Cold: Air masses colder than the surfaces over which they are moving, hence with a tendency toward increasing lapse rate and specific humidity.

(c) Indifferent: Air masses at the same temperature as the surfaces above which they occur.

(d) Unknown: Air masses whose temperatures relative to the underlying surfaces are unknown.

Classes (a) and (b) are the really important ones for this discussion; (c) applies primarily to air masses at their sources, or at least only to stagnant synoptic situations; (d) is of little significance, for as we shall see presently the properties of warm and cold masses are so distinctive that an experienced observer can readily detect them without the aid of any instrumental observations.

Although this classification of air masses might not be of as much assistance to the weather forecaster as the first method outlined above, it has the following definite advantages, in particular for the climatologist:

(1) It is perfectly general, applying equally well in polar and equatorial regions. It must be emphasized that the warm and cold designations indicate nothing about the actual temperature of the air mass itself, but only its temperature relative to the underlying surface. In fact, it is readily seen that cold air masses will tend to predominate at low latitudes, warm air masses at high latitudes. Furthermore, the transition from a warm to a cold or a cold to a warm air mass can take place very suddenly, and is especially likely to happen in summer and winter with the movement of air from land to water or vice versa. It will be found that such a change is followed by a very rapid adjustment of the characteristic properties of each mass, as outlined below, to those required for its new classification, at least at lower levels. A variable life

history of the mass will be indicated by variable characteristics at different levels, the older influences appearing at the upper levels.

(2) The detection of the warm and cold mass differences is so easy to make that an experienced observer can usually classify the prevailing type of air mass without the aid of instruments or synoptic chart. The properties to be noted and the differences characteristic of warm and cold masses, according to Bergeron may be summed up briefly as follows:

(a) Lapse rate: The cold mass will have a steep lapse rate (equal to or greater than the saturation adiabatic), and the warm mass a stable lapse rate, probably well-marked stratification, and often even inversions in the actual temperature lapse rate. Although the direct measurement of the lapse rate requires instrumental observations at the ground and in the free air, a reliable qualitative estimate of the steepness of the lapse rate may be made by direct observation of properties (b), (c), (d), and (e) below.

(b) Turbulence: Because atmospheric stability tends to damp out the eddy energy of mechanical turbulence and to prevent convective turbulence, it follows that the winds in warm air masses are much less gusty than in cold masses. This difference is so marked that it is readily detectable by any trained observer, and is quite striking in anemograph records. Bergeron has found in one clearly marked transition from a typical warm mass to a typical cold mass that although the prevailing wind velocity was reduced by one-half, the absolute magnitude of the variations in wind velocity due to gustiness remained practically unchanged.

(c) Horizontal visibility: Since a steep lapse rate favors convective turbulence and the upward spread of mechanical turbulence, it tends to effect a uniform distribution throughout the atmosphere of both moisture and the solid impurities, dust, and smoke. Therefore in warm air masses the obscuring dust and smoke are kept at low levels, particularly below any marked inversions. Consequently inversions result in haze and smoke layers sharply bounded at their upper edge. And in general, in warm masses visibilities are markedly poor at low levels, markedly good at upper levels, whereas in cold masses just the reverse is true.

(d) Cloud forms: The effect of dust on horizontal visibilities in warm and cold air masses is accentuated by the typical condensation forms. Since the same distribution of water vapor as of dry dust is typical of warm and cold air masses, it follows that in warm-air masses condensation tends to take place at low levels, resulting characteristically in either surface fog or a low thick stratus deck. In cold-air masses, on the other hand, the moisture is carried up to cooler levels by convective turbulence, the condensation occurring aloft as cumulus or cumulo-nimbus clouds, usually only a broken cloud with excellent visibilities below.

(e) Precipitation forms: Evidently the typical form of precipitation in the warm-air mass, if any occurs, will be of the mist or drizzle type, from a low stratus or nimbus, and rather small in amount. In the cold-air mass the typical form will be the instability shower, of short duration, but frequently heavy. Hail and thunderstorms will belong to this type. All the typical warm and cold air mass characteristic condensation forms will be more in evidence and more nearly complete in the case of maritime than of continental air masses, due to the greater moisture content of the former. The differences in precipitation forms in these two air masses become particularly significant in the case of steady air movement

on a high coast line or against any marked orographical barrier. In the case of the stable warm-air mass the tendency is to a continued stratified air flow which will resist vertical displacement and seek the easiest way around rather than over the obstacle. Hence the warm air drizzle rain is comparatively little intensified by orographical influences. On the other hand, in the unstable or conditionally unstable cold mass such an obstacle furnishes just the needed initial impulse to start extensive overturning of the atmosphere. Therefore, on the windward side of orographical barriers the cold-air mass may be expected to deposit copious precipitation in an almost unbroken sequence of heavy showers.

From the above considerations it is evident to what a large extent the commonly observed meteorological elements, visibility, gustiness, cloud forms, and type and amount of precipitation depend upon the prevalence of the warm or cold air mass type. And since climate is only the integral over a period of time of the daily weather, it is obvious that the predominance of one or the other of these air mass types will be a controlling factor in the climate, and will in itself serve to a considerable degree to classify and explain the climate. Therefore Bergeron concludes that the first thing to be done to develop a dynamic climatology is to record regularly by direct observation the prevailing air mass type at all stations whose records are to be used for climatological purposes, just as is done with any meteorological element. A trained observer could do this with little difficulty.

But this is only half the picture. It remains to take into account the irregular variations that go with migratory cyclones and anticyclones, and these tie up with the problem of the genesis and displacement of fronts. Quite as important as the characteristic weather phenomena belonging to each of the air mass types, are the phenomena which occur at the boundaries or fronts between air masses. Charts showing the mean pressure distribution over the northern or southern hemisphere for a given month, or maps of the prevailing winds such as those of Köppen, indicate clearly the tendency to the existence of more or less permanent regions of seasonal high and low pressure which dominate the mean air movement over the greater portion of the earth's surface. Such semipermanent areas of high and low pressure are sometimes referred to as "centers of action", for they are the fundamental thermodynamic units controlling the general circulation. Their essential cause is found in the thermal differences existing in the troposphere over large areas following the establishment of convective or radiation equilibrium in response to differences in the earth's surface. Examples of well-marked centers of action are the Aleutian and Icelandic lows and the north continental highs in winter, and the Azores and Pacific highs which are best developed in summer. It is the existence of these centers of action that is responsible for the large branches in the general circulation which enable us to speak of extensive air masses with characteristic properties. A chart of prevailing winds will show furthermore that there are certain regions where air currents or air masses of widely different origin and properties tend to be brought into more or less direct opposition. Such opposing trends in the movement of air masses of northerly and southerly origin evidently tend to greatly intensify, locally, the normal poleward temperature gradient, that is, they constitute a region of marked front formation, or what Bergeron calls frontogenesis. Correspondingly there are also regions of marked divergence or dissipation of the horizontal temperature differences, a process which Bergeron calls

frontolysis. These two processes are particularly important because they largely determine the activity of the migratory cyclones and anticyclones. It must be emphasized, however, that on any particular occasion the actual position of the front between two characteristic branches of the general circulation may be very far removed from the mean position as indicated by the line of convergence of the wind systems on the mean wind charts. On the other hand, if we designate the mean position of such a region of frontogenesis as a climatic front, then we can say that such a climatic front will be a region of maximum frequency of migratory cyclones. Such a region which will be characterized in its climate by a maximum frequency of warm, cold, and occluded front passages with their attendant cloud systems and typical rain belts, and a maximum frequency of change of the prevailing air mass type. Bergeron has represented, on the basis of Köppen's mean wind charts for the northern hemisphere in January and July, respectively, the winter and summer positions of the principal climatic fronts on the northern hemisphere, and shows in general how the resultant scheme fits the observed facts. He distinguishes between the arctic, the polar, and the tropical fronts. The arctic fronts are the most northerly, the air masses to the north coming directly from the arctic. On the polar fronts of middle latitudes we find the contrast to be essentially that between the subpolar and the subtropical air masses. On both of these fronts there are large temperature differences. Therefore the arctic and polar fronts are characteristically regions favorable to the genesis and maintenance of extra tropical migratory cyclones, with all the weather sequences which that implies. The tropical fronts, on the other hand, are distinctly different. They represent essentially convergence of subtropical and tropical air masses, whose temperature differences are characteristically small. They are primarily regions of light variable winds between the prevailing wind systems of the subtropics and tropics, such as the doldrums. Hence they are characterized by oppressive heat and over the oceans by high humidity, heavy instability showers, and under favorable conditions even by tropical hurricanes, but not by clearly marked front passages or typical warm and cold front rain belts.

Obviously the climate at any place depends on the prevailing air mass type, and the frequency of front passages, i. e., nearness of the climatic fronts. Both of these in turn depend upon the position, extent, and activity of the different centers of action. Therefore the fundamental problem of a dynamic climatology which aims to present the underlying dynamic and thermodynamic phenomena of the atmosphere in their entirety is to account completely for the mean activity of the centers of action. The first step toward the solution of this problem is the development of some satisfactory method of representing the state of activity of the centers of action, in order that normal and abnormal conditions may be clearly represented and recognized. For this purpose Bergeron used Köppen's mean wind charts as the best means at hand for a preliminary study.

An understanding of the dynamic and thermodynamic factors controlling the centers of action will explain not only the mean activity of these atmospheric phenomena (climate), but also variations in and departures from this mean activity. The shortest and most irregular of these changes we refer to as changes in the weather. For instance, Bergeron shows, in accordance with Köppen's mean wind chart for January, that for this month in the eastern United States the climatological front (polar) between the cold continental air masses of the North

American winter anticyclone and the warm maritime air masses belonging to the circulation of the Bermuda high (westward extension of the Azores high) extends from southern Florida northeastward to the vicinity of Bermuda and on into the north Atlantic. Thus Köppen indicates prevailing northwest winds on the north Atlantic and northeast on the south Atlantic coast. On the other hand, we know that this front, even in winter, may be displaced northward as far as to the Canadian border, and again far southward until lost in the trade winds as the successive warm and cold outbreaks belonging to the two circulations advance and recede. Always the cyclones tend to develop and move along the front as it is displaced. Such changes as these constitute weather, and have no place properly in a discussion of climate. Yet in the aggregate they determine climate, and as we shall see presently, no hard and fast line can be drawn between weather and climate, either in definition or in the controlling factors.

Besides the irregular variations of a few days or weeks which constitute what we call the weather, there have long been observed, statistically, anomalies of the various meteorological elements of months and even years, some of which recur with a certain degree of regularity. Such anomalies will usually be found associated with some abnormality in activity or position of one of the centers of action. Whether variations such as these will be classed as climatic changes or not depends entirely on the arbitrary choice of the period of time which shall be considered sufficient to determine a climate. Yet we know that even if centuries are used in establishing climatic means, still changes of climate take place. There occur meteorological anomalies of every length from a few days to thousands of years, and of every degree of irregularity, yet they are all apparently associated with the same sort of abnormalites in the centers of action, whatever the underlying causes. Hence it becomes evident that in climatology, as well as in the study of the daily weather, it is necessary to consider not only mean or normal conditions, but also the disturbing factors.

A good instance of an anomaly lasting a few months is that of the drought which reached its peak in the eastern United States during the summer and autumn of 1930. During that time the Bermuda high was unusually well developed to the westward, therefore, persistently predominant in the circulation of the southeastern United States, so that the polar front, or cyclone path, was displaced northward from its normal position. As a consequence the normal cyclonic or frontal rain was largely missing in the eastern United States, and this in turn lessened the evaporation from the earth's surface which probably is the source of the greater part of the moisture of summer showers and thunderstorms. There are many well known more or less irregularly periodic displacements of this sort of considerably longer duration. Probably the best known and most studied of these longer period displacements of the climatic fronts are those connected with the 11-year sun spot cycles. As to the reality of many of these changes there is not the slightest doubt, but in the dynamic or thermodynamic explanation of them not even a beginning has been made. Some of the factors, which have been suggested as of importance in the control of climate and climatic changes (see Humphrey's Physics of the Air, Pt. V), may be listed as follows:

(1) *Radiation.*—(a) Solar: Variations in the solar constant, such as those belonging to the 11-year sunspot cycle and possibly others of longer or shorter duration.

(b) Atmospheric: Changes in the atmospheric composition (especially the amounts of water vapor, ozone, or carbon dioxide) or of its content of impurities which reflect or scatter solar radiation (especially volcanic dust).

(2) *Changes in the earth's surface.*—(a) Glaciation: This favors both by radiation and reflection further cooling of the overlying atmosphere and the strengthening of local anticyclonic circulation.

(b) Desiccation: Increasing aridness over a portion of the earth renders that region one of greater extremes in climate.

(c) Distribution of land and water: Changes in the position or ratio of land and water areas must affect the nature of the general circulation profoundly, for they seem principally to determine the centers of action. Furthermore, orographical changes may greatly affect the atmospheric circulation and climate, while the influence of similar changes in submarine orography on the oceanic currents may have an equally far-reaching effect on climate.

(d) Ocean surface temperatures: Anomalies in ocean surface temperatures and currents much like those in the atmosphere are generally recognized phenomena. These may in part be caused by atmospheric irregularities, but certainly there are also independent factors involved. These must be taken into account especially in explaining the short period atmospheric anomalies. It is very difficult to distinguish between cause and effect in atmospheric-oceanic interactions.

(3) *Persistent tendencies in the circulation of the substratosphere.*—It has been shown analytically and statistically that for short period surface pressure variations the warm and cold air currents of the substratosphere (actually warm and cold here, not relative to the surface) play an important rôle. Even important irregular change in the greater centers of action are frequently explained in this way. Clearly then, whatever the dynamic and thermodynamic controls of the circulation at the base of the stratosphere, persistent or variable tendencies in the circulation here will have corresponding secondary effects at the earth's surface.

It is scarcely necessary to point out how fundamental for the problem of long range weather forecasting is the development of a comprehensive dynamic meteorology in the sense outlined in this paper. In fact, the two problems are identical, for such a dynamic climatology is nothing other than the physical basis of long-range forecasting. At present there are numerous schools of thought which have been developed in connection with this problem, each based on only one or two of the above-mentioned factors of climatic control, and usually mutually exclusive and even antagonistic. Furthermore they are entirely empirical, based on experience or correlations and utterly lacking in any attempt at dynamic explanations. A dynamic climatology that can finally explain the intensity and displacements of the centers of action and of the climatic fronts will make possible the forecasting over considerable periods not only of the cyclonic activity and frontal rain, but also of the prevailing air mass types with all the attendant weather phenomena.

To sum up, we might say that if a dynamic climatology is to aim at a presentation of the several complete thermodynamic units controlling the climate of a region rather than the unrelated distribution of the individual meteorological elements, it should be developed somewhat as follows:

(1) Some method of representing the position, horizontal extent, and degree of activity of the different centers of action should be chosen, so that mean values and long-period departures from the means may be found and

studied. For this purpose Bergeron has made use of Köppen's mean wind charts as the best available criterion.

(2) Mean positions and long-period departures from the mean positions of the climatic fronts must be noted. Explanation of departures from the normal position of such zones, i. e., displacement of the belts of maximum storminess, or cyclone paths, must be looked for in the dynamic or thermodynamic factors (see list above) controlling the particular center of action whose displacement or changed activity is responsible for the displacement of the climatic front.

(3) Finally there is required the systematic observation of the frequency of occurrence of warm and cold air masses at each station, and the relation of all the meteorological elements, especially the hydrometeors, to the prevailing air mass type. The frequency of change from one air mass to another should give in temperature regions a measure of the proximity and activity of the climatic front, and an indication of the contribution of active front passages to the climate of the region, particularly the precipitation and cloudiness.

WINDSTORM IN THE LOS ANGELES AREA NOVEMBER 22, 1930, AND SOME EFFECTS OF WIND FLOW IN A MOUNTAINOUS REGION

By GEORGE M. FRENCH

[Weather Bureau Office, Los Angeles, Calif., July, 1931]

Near midnight of November 21, 1930, one of the strongest winds of record began in the Los Angeles area and continued until about midnight of November 22. Winds aloft and on the surface were from the northeast except where they were deflected by topography.

Following the passage of a low over the southern portion of the western plateau region on November 18, 1930, a high pressure area moved in rapidly from the Pacific Ocean over the Northwestern States and when reaching the plateau region became almost stationary as is common in that region especially during the early winter months. This high built up rapidly being reinforced by additional ocean highs and as shown on the 8 p. m. synoptic chart of November 21, it was central over Idaho, eastern Oregon, and western Montana with a pressure of 30.82 inches. The pressure gradient had by this time become quite steep between the plateau and the coastal valleys of California and the high was still increasing in energy.

The influence of this high was little felt in southern California as far as either surface winds or those aloft were concerned during the day of November 21, 1930, but a little before midnight on that date surface winds increased rapidly and became strong with frequent gusts of gale force. The next morning, November 22, the synoptic chart showed the high central in Idaho and northwestern Wyoming with the highest reading at Yellowstone, 31.02 inches, reduced to sea level.

Three hourly airway weather maps of California for 11 a. m., 2 p. m., and 5 p. m., eastern standard time, are shown by figures 1, 2, and 3. As the map is on quite a large scale, isobars are drawn for every 0.05 inch difference in pressure. These maps show the steep gradient that prevailed over the mountains on November 22 and the relatively low pressure on the lee side of the mountains, which is largely due to the strength of the wind.

From experience the writer believes that under ordinary pressure gradients, mountains as high and as precipituous as the San Gabriel Range act as a barrier to north winds in the Los Angeles area. In such cases high winds proceed southward over the mountains and remain aloft, gradually lowering and reaching the surface in the vicinity of the ocean shore line or farther out, leaving the Los Angeles area in light to moderate variable winds. However, in such cases the wind pours through the low points in the mountains, as for example Cajon Pass, and frequently proceeds southward at gale force through Santa Ana Canyon in the Santa Ana Mountains and thence southward to the ocean, thus producing the "Santa Ana" as the wind of this type has been popularly called in southern California. I once had the opportunity to observe such a wind from the top of Santiago Peak.

The course of this rapidly moving air was easily traceable by the dust and could be followed in that manner from Cajon Pass to the ocean.

It appears, by study of winds in the Los Angeles area, that if the gradient is quite steep between the plateau high and the coastal area that high northerly winds in passing over the mountains will not only reach the surface in lee of low passes but will also follow the contour of the lee side of the high mountains and in that case high northerly winds are general over the whole Los Angeles area as was the case on November 22, 1930.

There were three points in and near Los Angeles where wind instruments were located at the time of the storm. They were located as follows: Weather Bureau office, Los Angeles; airport at Alhambra, and the Weather Bureau airport station, Glendale. The writer was located at the latter point. The strength and duration of the wind was quite similar at Glendale and Alhambra but the velocities were lighter and the duration much shorter at the Weather Bureau office, Los Angeles, a condition that frequently prevails in times of high northerly winds. The Weather Bureau office in Los Angeles is remarkably free from high northerly winds although the exposure is excellent.

The high winds at Glendale had two maximum periods on the surface, 2 to 4 a. m. and 12:30 to 4 p. m., with gusts in excess of 60 miles per hour during the latter period. As far as could be ascertained, the highest winds aloft occurred near the middle of the forenoon.

The first upper air observation on the day of the wind storm was attempted at 3 a. m. but with several attempts only 3 minutes were secured due to dust. Shortly before 9 a. m. upper air observations were again attempted and after several trials one was secured of nine minutes with an indicated altitude of 5,600 feet. In each of the attempts the balloon moved southwestward rapidly in the beginning then was retarded at approximately the same length of time after release and then would again move out much more rapidly than before. The first attempts were lost soon after reaching the second high velocity either due to dust or to the vibration of the theodolite.

In Figure 4 a cross section of the mountains and valley north and south and passing through the airport station at Glendale is represented. Wind flow over the mountains and valleys is represented by arrows flying with the wind giving my idea of both the nature of the flow over the mountains and the relative speed. The relative speed is indicated by the length of the arrows, longer arrows representing greater speed. This is based on available data and the general knowledge that I have gained mostly in the aerological work of wind flow over a mountain range.